OPEN ACCESS Freely available online

M – 00314 | Review Article

Applying the Landscape Services Concept in Landscape Research: A Review

Sining Zhang

Department of Landscape Architecture, School of Architecture, Southwest Jiaotong University, Chengdu, 611756, Xipu Campus, Chengdu, Sichuan Province, P. R. China.
E-mail: ZSNing@swjtu.edu.cn | https://orcid.org/0000-0001-6273-0891

Abstract

Considerable attention has been given to the concept of landscape services since the development of research on ecosystem services. However, from the landscape perspective, there are numerous challenges and unanswered issues regarding landscape services. The objective of this paper is to provide a comprehensive review about the state-of-the-art concept of landscape services and its corresponding approaches while trying to set up a foundation for further discussions. First, the definitions and classifications of ecosystem services and landscape services are presented. Second, the relationship between ecosystem services and landscape services, and the studies that integrate ecosystem services into landscape research, are discussed. Finally, an overview is provided concerning research conducted at multiple scales, and the various assessment and quantification methods used for mapping and studying landscape services, even though there are many challenges in establishing a comprehensive approach for such quantification and mapping.

Introduction

The ecosystem services (ES) approach is an effective way to strengthen the link between ecosystems and human well-being. Since the late 1960s (Odum and Odum, 1972), ES have been receiving significant attention in the scientific community. The terminology 'ecosystem services' was first used by Ehrlich and Ehrlich (1981). It represents a critical research agenda in the trans-disciplinary field of ecological economics, aiming to bridge the gap between ecosystem ecology and environmental and resource economics (Costanza *et al.*, 2017) to gain public interest in biodiversity conservation, the societal and economic value of natural assets is emphasised. The mainstreaming of ES was marked by two key publications: Daily (1997) and Costanza *et al.* (1997). In the two decades since its development, an extensive list of publications has been generated regarding key issues such as definitions, classification, valuation and assessments, modelling, and mapping approaches. Furthermore, various associated topics have become key issues in multidisciplinary fields of research. The concept of landscape services (LS) is one of them.

The terminology 'landscape services' (LS) is becoming increasingly popular because it is always regarded as a synonym for ES, especially when referring to landscape research. However, these terms are not always the same. ES act as a bridge between ecosystems and human well-being. However, the landscape is a socio-natural system - a holistic, appreciable and dynamic entity (Antrop, 2000) - that changes based on interactions with human activities. This means that landscapes involve natural ecosystems and total human ecosystems. Landscape science helps better understand the effects of the spatial distribution of human activities on landscape processes and structures through which services are derived (Müller *et al.*, 2008). LS, focusing on the relationship between human interactions and landscape processes and structures, are topical issues in the context of landscape ecology and sustainability (Termorshuizen and Opdam, 2009).

There are many arguments supporting the importance and application of LS in landscape research. For example, the effective use of LS for land use management and planning (De Groot and Hein, 2007), such as the analysis of landscape patterns, processes, and functionality as a premise for land use planning, which is an established process in Central and Eastern Europe. Another application is during policy-making processes and landscape planning, i.e., the assessment and planning of urban green infrastructure (Gulickx *et al.*, 2013). It also supports the development of landscape sustainability (Wu, 2013).

However, there are still many obstacles concerning LS, such as the typology, the relationship with ES, evaluation and visualisation approaches, and practical application in landscape planning and research (De Groot *et al.*, 2010). Several reviews have been published to clarify the development of ES, but not LS. The need to differentiate LS from ES in landscape research using a coherent and unified approach is essential, especially because this confusion can lead to the formation of a non-standard discipline with a blurred boundary. Additionally, LS alone should be treated as the common ground for interdisciplinary research.

This study aims to provide a thorough knowledge base that distinguishes LS from ES and seeks solutions for incorporating the concept of LS into landscape planning and decision-making processes while contributing to the ongoing discussions. Section 2 presents the state-of-the-art concept of LS (definition and classification). Section 3 provides a coherent knowledge base regarding the relationship between ES and LS (similarities and differences), and the integration of ES into landscape research. A research overview of LS is provided (Section 4), incorporating multi-scale studies, and different assessment and mapping methods. In conclusion, future development prospects are discussed (Section 5).

Typology of Landscape Services

Ecosystem Services

Many researchers have discussed the definition of ES (Costanza *et al*., 1997, 2017; De Groot *et al*., 2002; MA, 2005), but a unified definition is still unavailable. Various definitions have been proposed in a multidisciplinary context. De Groot (1992) explained ES as 'the capacity of natural conditions and processes to sustain human needs', emphasising ecological processes and structures. Cairns (1997) believes that ES are functions that promote human survival and development. However, Boyd and Banzhaf (2007) presented ES as biological components, rather than invisible ecological processes and functions, directly utilised for human well-being. Similarly, Fisher, Turner and Morling (2009) proposed that ES are 'the aspects of ecosystems utilised (actively or passively) to produce human well-being' (p. 645).

Currently, the definition of ES proposed by the Millennium Ecosystem Assessment (MA) may be the most widely used and recognised; ES are defined as 'the benefits from ecosystem functions and processes, which are favourable for human well-being, directly or indirectly' (MA, 2005, p. V). The term 'services' is used to denote goods, functions, and services. Regardless of the existing controversy, an extensive discussion has been triggered globally about ecosystem functions, goods, and services. Besides, the TEEB (The Economics of Ecosystems and Biodiversity) study defined ES as "the direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010).

Definition of Landscape Services

The concept of LS has introduced a new approach for studies on multi-functional landscapes and spatial heterogeneity at the landscape scale. For instance, such alternative methods can be used to tackle the issue of quantifying invisible services (e.g., cultural services / aesthetic values). This concept was first used in a paper about the urban agricultural sector (Leones, 1994). Termorshuizen and Opdam (2009) proposed the terminology 'landscape services' to link landscape ecology and sustainable development, defining LS as 'a spatial human-ecosystems that offers additional ecological, social, and economic values based on human activities and landscape changes'. This concept considers the relationships among the locals, stakeholders, and the environment, promoting further collaboration across scientific disciplines and highlighting landscape patterns.

Currently, even though there are numerous corresponding publications, ambiguous boundaries still exist due to the lack of a unified theory about LS. Some of the key relevant arguments on the definition of LS can be seen in table 1, which aims to clarify the advance in the understanding of LS. This table shows that most researchers consider ES and LS as synonyms; the only difference being the matter of scale, rather than anything fundamental. However, from the perspective of specific disciplines (landscape planning / landscape ecology) and different stakeholders, 'landscape service' is a distinct term. Therefore, a clear dichotomy between the ES and LS concept is essential.

Classification Systems of Landscape Services

Significant efforts have been made by researchers to develop a clear catalogue for ES assessment, valuation, modelling, and policy-making (i.e., Daily, 1997; Syrbe and Walz, 2012), after Costanza *et al*. (1997) provided a list of seventeen services. Classification systems for ES mainly depend on ecosystem processes and functions. The typology put forth by MA is classified into four broad types of ES: provisioning, regulating, supporting, and cultural services (MA, 2005). However, the typology of ES does not consider the spatial pattern, and landscape elements and characteristics. A systematic typology and comprehensive framework for LS are currently lacking.

Table 1: Definitions of Landscape Services

Source	Definition	Key points
Termorshuizen and Opdam (2009)	'A unifying multi-disciplinary common ground integrated into multifunctional, actor-led landscape development, and a bridge between landscape ecology and landscape sustainability'. LS are a specification, not an alternative to ES. LS are a core application of landscape ecology based on interdisciplinary science development.	It is a generally recognised definition base on landscape structure, functions, and values, which argues that LS help bring landscape planning processes from theory to practice.
De Groot et al. (2010)	LS are defined as 'the capacity of ecosystems to provide goods and services that satisfy human needs'.	They consider ES and LS the same, without fundamental differences, mainly a matter of scale.
Willemen et al. (2012); Willemen (2010)	LS are 'the flow of goods and services provided by the landscape to society'.	A modelling approach is elaborated to visualise the regional spatial and temporal dynamics in the LS provided.
Syrbe and Walz, (2012)	The term 'ES' is enlarged to 'LS'. LS are a broader perception manner and highlight the spatial characteristics and relationships.	The LS assessment through landscape metrics integrates three different service provision areas.
Wu (2013)	'ES provided by multiple landscape elements in combination as emergent properties'.	LS are the core of landscape sustainability science in a changing landscape. But this narrow definition of LS refers to ecological services generated by landscape patterns or configurations (Bastian et al., 2014).
Bastian et al. (2014)	ES and LS are synonyms. LS are 'the contributions of landscapes and landscape elements to human well-being'.	They proposed that spatial aspects, landscape elements and characteristics, and landscape planning impact the LS provision.
Hermann et al. (2014)	'All goods and services that landscapes provide for well-being'.	They argue that LS are more related to human habitats and cultural patterns, rather than natural processes and conservation.
Vallés-Planells, Galiana and Van Eetvelde (2014)	LS involve 'the social dimension of landscapes and the spatial pattern resulting from both natural and human processes in the provision of benefits for human well-being'.	They developed a classification for LS based on the Common International Classification of Ecosystem Services (CICES) and a review of the literature.
Westerink et al. (2017)	LS are delivered effectively by the biophysical landscape conditions, with a new role of enhancing social capital in landscape governance.	LS are more suitable for studying social capital and ecological networks.

In order to integrate ES at the landscape scale easily and to apply these services in landscape planning and decision making, researchers proposed classification systems for LS adapted from the classification systems for ES. De Groot *et al*. (2010) provided a categorisation similar to the ES classification since they consider ES and LS to be synonymous. Vallés-Planells, Galiana and Van Eetvelde (2014) developed a categorisation that is built on the CICES and combines the social dimension of landscapes, including three categories: provisioning, regulation and maintenance, and cultural and social life fulfilment services. Human well-being, as well as social and cultural dimensions have been considered at the landscape scale. More specifically, it emphasises the all-inclusive nature of landscapes and the benefits for human welfare, while considering human satisfaction. For example, health, enjoyment, self-fulfilment, and social fulfilment are included in the cultural and social services (See Table 2). Bastian *et al*. (2014) recommended a typology for LS (or ES), including provisioning, regulating, and social-cultural services, which clearly considers spatial aspects, and landscape characteristics and elements related to landscape planning and landscape ecology. ES and LS are considered to be the same only when the landscape dimension has been carefully considered.

Table 2 shows a comparison (differences and similarities) between the selected four ES and two LS classification systems. In this table, Costanza *et al*. (1997) classified ES into seventeen specific services. From the first column to the fourth column (Costanza *et al.*, 1997; MA, 2005; TEEB, 2010; Haines-Young and Potschin, 2010a), different classification systems of ES are shown. Vallés-Planells, Galiana and Van Eetvelde (2014) and Bastian *et al*. (2014) developed LS classification systems based on ES systems that refer to landscape related aspects. Besides, in some cases, a particular category serves two purposes and hence, the additional service theme is mentioned in parentheses.

It should be noted that these systems are broadly similar, especially the ones related to ES. Since the classification systems for LS are generally derived from the ES typology, it is essential to seek a unique, practical, scientific, and rational classification system for LS. On one hand, landscape features, distinct service delivery processes, their relationship to human values, and the application in decision making should be taken into account for an effective classification system. This means that landscape patterns and spatial characteristics are essential. On the other hand, apart from being pleasant and joyful amenities (Haines-Young and Potschin, 2010b), cultural services are also essential when considering services that fulfil personal and social human satisfaction. Furthermore, it is hard to evaluate cultural services without information on spatial patterns and landscape functions.

Table 2: Comparison (differences and similarities) between seven selected main classification systems for ecosystem services and landscape services applied in many research areas (Costanza *et al*., 1997; MA, 2005; TEEB, 2010; Haines-Young and Potschin, 2010a; Vallés-Planells, Galiana and Van Eetvelde, 2014; Bastian *et al*., 2014)

Source / Theme	Costanza et al. (1997) Categories	Millennium Ecosystem Assessment (MA, 2005) Categories	TEEB (2010) Categories	CICES 2010 (Haines-Young and Potschin, 2010a) Categories	CICES 2010 Classes	Vallés-Planells, Galiana and Van Eetvelde (2014) Categories	Vallés-Planells Classes	Bastian et al. (2014) Categories	Bastian et al. Classes
Provisioning Services	Food production	Food	Food	Nutrition	Terrestrial plant and animal	Nutrition	Terrestrial plant and animal	Food	Food and fodder plants
									Livestock
					Marine plant and animal		Marine plant and animal		Wild fruit and game
					Freshwater plant and animal		Freshwater plant and animal		Wild fish
									Aquaculture
	Water supply	Freshwater	Water		Potable water		Potable water	Renewable raw materials &other	Freshwater
	Raw materials	Fibre	Raw materials	Materials	Biotic materials (Non-food plant fibres; Non-food animal fibres;	Materials	Biotic materials (Non-food plant fibres; Non-food animal fibres;		Fibre
									Timbers
		Ornamental resources	Ornamental resources						Other natural materials

Source \\ Theme	Costanza et al. (1997) Categories	Millennium Ecosystem Assessment (MA, 2005) Categories	TEEB (2010) Categories	CICES 2010 (Haines-Young and Potschin, 2010a) Categories	Classes	Vallés-Planells, Galiana and Van Eetvelde (2014) Categories	Classes	Bastian et al. (2014) Categories	Classes
		Bio-chemical & natural medicine	Medicinal resources		Ornamental resources; Genetic resources; Medicinal resources)		Ornamental resources; Genetic resources; Medicinal resources)	natural resources	Bio-chemicals & natural medicine
	Genetic resources	Genetic resources	Genetic resources						Genetic resources
					Abiotic materials		Abiotic materials		
				Energy	Renewable biofuels	Energy	Renewable biofuels		Bioenergy
					Renewable abiotic energy		Renewable abiotic energy		
						Daily activities	A place to live/work/move		
Regulating services	Waste treatment	Waste treatment	Waste treatment	Regulation of waste	Bioremediation	Regulation of waste	Bioremediation		
					Dilution and sequestration		Dilution and sequestration		
				Regulation of physical environment	Water quality regulation	Regulation of physical environment	Water quality regulation	Hydrological services	Water purification
	Soil formation	Soil formation (supporting service)	Maintaining soil fertility		Pedogenesis and soil quality regulation		Pedogenesis and soil quality regulation	Pedological services	Maintenance of soil fertility
	Climate regulation	Climate regulation	Climate regulation		Atmospheric regulation		Atmospheric regulation	Meteorological services	Climate regulation
									Noise protection
	Gas regulation	Air quality regulation	Air purification	Flow regulation	Air flow regulation	Flow regulation	Air flow regulation		Carbon sequestration
									Air quality regulation
	Water regulation	Water regulation	Regulation of water flow		Water flow regulation		Water flow regulation	Hydrological services	Water regulation
	Erosion control	Erosion regulation	Erosion regulation		Mass flow regulation		Mass flow regulation	Pedological services	Erosion prevention
	Disturbance regulation	Natural hazard regulation	Disturbance prevention						
	Biological control	Disease regulation	Biological control	Regulation of biotic environment	Pest and disease control	Regulation of biotic environment	Pest and disease control	Biological services	Regulation of pests and diseases
		Pest regulation							
	Pollination	Pollination	Pollination		Lifecycle maintenance & habitat protection		Lifecycle maintenance & habitat protection		Pollination
	Refugia (supporting service)		Lifecycle maintenance						
			Gene pool protection (habitat service)		Gene pool protection		Gene pool protection		Conserving biodiversity
						Regulation of the spatial structure	Connection of spaces		
							Buffer disturbing use		
							Provision of spatial complexity		
Supporting services	Nutrient cycling	Photosynthesis; Primary							

Source / Theme	Costanza et al. (1997) Categories	Millennium Ecosystem Assessment (MA, 2005) Categories	TEEB (2010) Categories	CICES 2010 (Haines-Young and Potschin, 2010a) Categories	Classes	Vallés-Planells, Galiana and Van Eetvelde (2014) Categories	Classes	Bastian et al. (2014) Categories	Classes
		production; Nutrient cycling; Water cycling							
Cultural services								Information services	Environmental indication
									Archive function
	Cultural (incl. aesthetic, artistic, spiritual, education, science)	Knowledge system	Information for cognitive development	Intellectual and experiential	Information& knowledge (scientific & educational)	Self-fulfilment	Didactic resources		Education and training
							Way-finding		
							Scientific resources		
		Inspiration	Inspiration for culture, art, and design				Source of inspiration		Intellectual and artistic inspiration
		Spiritual and religious values	Spiritual experience	Symbolic	Spiritual		Spiritual experience	Psychological goods and services	Ethical, spiritual, religious values
		Aesthetic values	Aesthetic information		Aesthetic & heritage (landscape characteristics, cultural landscapes)				Aesthetic values
		Sense of place				Social fulfilment	Place identity		Identification
		Cultural heritage values					Sense of continuity		
		Cultural diversity							
		Social relations					Social interactions		
	Recreation	Recreation and ecotourism	Recreation & tourism	Intellectual and experiential	Recreation and community activities	Enjoyment	Passive enjoyment	Psychological services	Recreation
							Active enjoyment		
						Health	Mental health		
							Physical health		

Relationship Between Ecosystem Services and Landscape Services

Similarities and Differences

The ES concept is an essential part of research on ecological economics. Assigning monetary value to the services provided by nature is not an innovative idea. McCauley (2006) argued that the term 'service' is a utilitarian approach towards nature, because only the goods and products that are considered valuable for human beings, and not for the landscape or ecosystems, are considered. However, owing to the fact that humans and other species all belong to the biosphere, Costanza *et al.* (2017) emphasised that ES should not only focus on human beings alone, but also consider other species in the world. Furthermore, ES recognise that human well-being and survival are closely related to nature; therefore, humans should show the appropriate understanding and gratitude towards nature.

The LS evolve from ES, but they do not have an owner-member relationship (Figure 1). A landscape includes different kinds of ecosystems (usually a mix of ecosystems), indicating that LS are a mixture and/or a superimposition of ES, with different functions at different scales (e.g., aesthetic attractiveness).

Furthermore, when compared to an ecosystem scale study, a regional ecological landscape is the most practical scale to conduct research on sustainable processes and mechanisms (Wu, 2013). It is also the bridge that links landscape ecology and sustainability science. However, landscape sustainability science is still in its formative stages, and few researchers have systematically studied the theories and methods related to regional ecological landscapes.

Both LS and ES highlight the link between ecosystems and human values and focus on the human dimensions of ecosystems. However, LS can describe the benefits provided by both natural and artificial landscapes, whereas ES focus on natural systems.
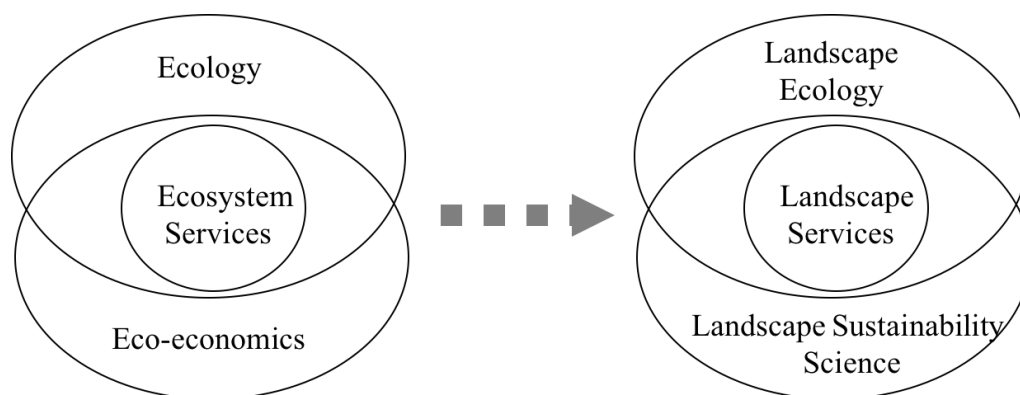
Figure 1: Chart of relationship between ecosystem services and landscape services. portray the effects of human activities.

The research on ES emphasizes the functional relationships between ecological processes and composition, but the spatial relationships between landscape structure and patterns are neglected. LS highlight the importance of spatial patterns and the spatial relationship between service providers and beneficiaries (Sun *et al.*, 2018). It also underlines the society property, since landscapes provide social benefits to human beings.

There is a visible indication to see the rapid development of ES research, which is the soaring quantity of literature. A search using SCOPUS on November 11, 2018, produced 19,461 papers using the term 'ecosystem service' in the title, abstract, or keywords between 1994 and 2018. There are over 2,000 papers from 2015 to 2018, and over 2,800 from 2017 to 2018 alone. The papers typically focus on valuation, quantification assessments, and mapping. Contrarily, there are only 99 papers employing the term 'landscape services' in the title, abstract, or keywords between 1994 and 2018 (SCOPUS, Figure 2), of which 86 papers were published in the last decade.

The number of publications on LS is only 0.5% of those on ES. An increase in the number of publications since 2005 can be observed in figure 2. Most of the papers with the term 'landscape services' in the title, abstract, and keywords, were published in *Ecological Indicators* and *Landscape Ecology*. Each of these journals published nine articles since 2009, followed by the *Shengtai Xuebao Acta Ecologica Sinica* (5 papers) and the *Sustainability Switzerland* journal (5 papers). Four papers were published in *Horttechnology* (2013 - 2016). The most important topics addressed were landscape planning, and the effects of landscape structure and patterns on the scale. Based on the data presented, collaborative efforts in LS research are absolutely imperative.
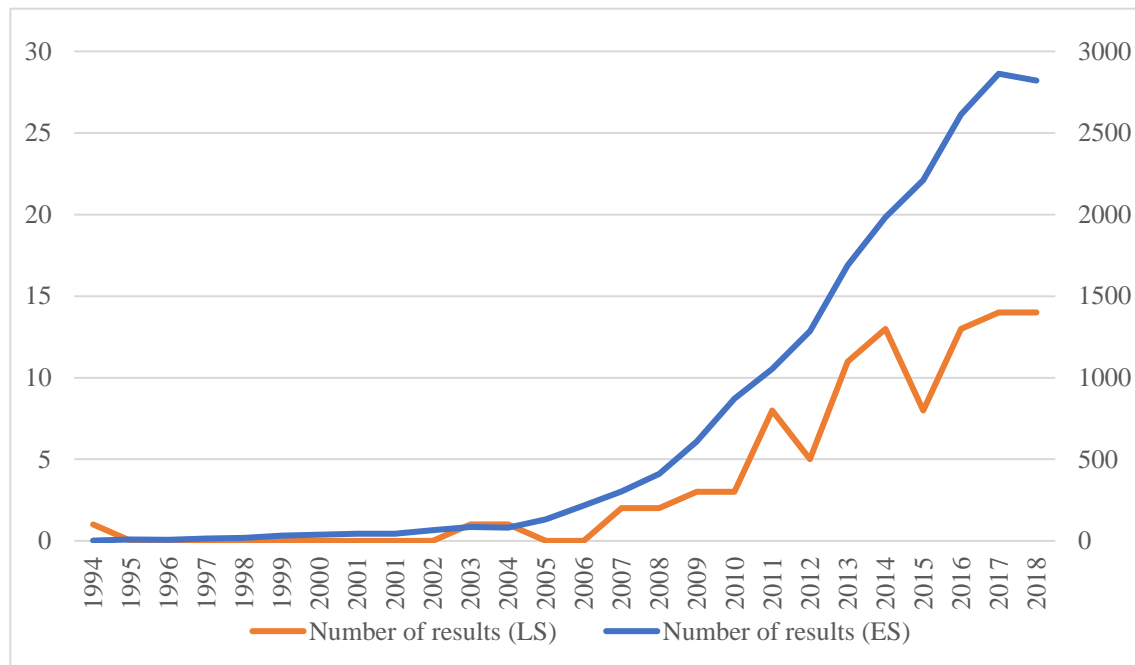
Figure 2: Comparison of published papers on ecosystem services and landscape services. Graphical representation based on SCOPUS search (November 11, 2018).

Integrating Ecosystem Services into Landscape Research

In the last decade, researchers have tried to integrate the concept of ES into landscape research. Using the search terms 'ecosystem services' and 'landscape' in the title in SCOPUS (November 11, 2018), 333 relevant papers were found, published between 2008 and 2018, with over 50 papers per year from 2016 to 2018 (Figure 3). 225 papers tackled case studies across the globe.

In general, ES and LS are considered synonyms only in the field of landscape planning (De Groot *et al.*, 2010). An abundance of research has been carried out on integrating ES and landscape planning, such as the impact of climatic and land-use change on ES (Lautenbach *et al.*, 2011), the impact of changes in landscape patterns on ES (Duarte *et al.*, 2018), the development and planning of green infrastructure (Liquete *et al.*, 2015; Zhang and Muñoz Ramírez, 2019), and, the advances in landscape planning (Ahern, Cilliers and Niemelä, 2014). LS are inevitably mentioned in these topics, because the LS concept is the key to analysing the relationship between spatial patterns and scales related to human activities.

Overview of Research Areas

Research Conducted at Multiple Scales

ES demonstrate a dominant role only at specific spatial-temporal scales (Hein *et al.*, 2006), as observed in studies on the supply, demand, and flow of ES are in a dynamic state at the different spatial (local, regional, national, and global) and temporal (short, medium, and long term) scales. It is important for stakeholders to analyse these scales in terms of varied interests and gain an insight into the applicable institutional scales for ecosystem management decisions. There is an increasing awareness of the significance of spatial-temporal scales when analysing and evaluating ES. For instance, Syrbe and Walz (2012) investigated the spatial characteristics of ES and their relationship with quantified measures of landscape structure. Hein *et*

OPEN ACCESS Freely available online

al. (2006) analysed the spatial scales of ES and elaborated the framework that enhances the applicability of ES valuation for decision making in the De Wieden wetland in the Netherlands. Wang and Dai (2020) identified the main factors affecting ES in the Heng-duan Mountain region.
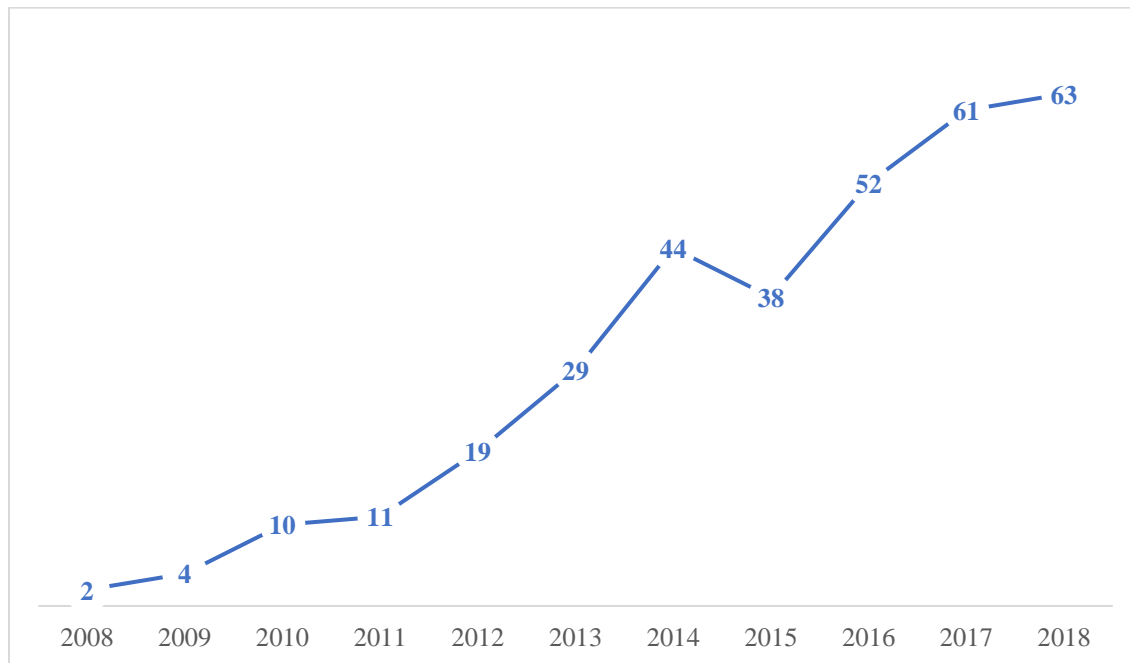

Figure 3: Number of published papers integrating the ecosystem services concept into landscape research.
Source: SCOPUS search, November 11, 2018

However, when ES are applied at the landscape scale, many functions are often lost or degraded, due to an excessive emphasis on landscape functions (Costanza, 2008). For example, an overemphasis of recreational functions may result in the destruction of historical heritage and biodiversity loss. Therefore, it is important to balance various landscape functions while exploring the relationship between the delivered services. In order to explain and analyse the complicated relationships of LS at various scales, it is essential to know the association relationship of different LS at different spatial scales (Aertsen *et al*., 2012). Also, it is necessary to consider the dominant services at the same spatial-temporal scale, and the coordination of services and functions at multiple scales that contributes to meeting various community demands.

Landscapes are constantly changing, resulting in a change in LS provision. Each of the LS has spatial heterogeneity. For example, climate regulation services, at the local scale, are presented as services that relieve urban heat island effects and maintain favourable weather (Niemelä *et al*., 2010; Young, 2010). At the regional scale, it has a positive influence on maintaining a habitable environment for residents and good weather conditions for food production (Serna-Chavez *et al*., 2014). On the global scale, it plays a crucial role in controlling carbon emissions and reducing global warming.

Therefore, before applying LS to landscape research and further decision-making processes, it is essential to consider LS in different scales at the same time. The transmission mechanisms of multi-scale ES and LS analysed with a spatial-temporal perspective requires further investigation.

Assessment Framework and Quantification Mapping

The assessment and mapping of ES aims to understand the process of transforming data to visualise the results regarding the spatial distribution of ES with advanced GIS technology that has proved to be a great instrument in decision-making (Sherrouse, Clement and Semmens, 2011), and landscape planning (Zhang and Muñoz Ramírez, 2019). In the published literature, there are four main methodologies:

(1) Literature survey method: It is based on the data applicability (Haines-Young and Potschin, 2009), but has high requisitions about the diversity and reliability of data.
(2) Modelling method (Nelson *et al.*, 2009): Most cases using it that neglect the landscape patterns and spatial heterogeneity.
(3) Assessment index method: It uses criteria and indicators to evaluate and map ES, including monetary evaluation methods, e.g., the market-valuing method (De Groot *et al.*, 2010), and, the value of monetization; and non-economic evaluation methods, e.g., the participatory, deliberative choice experiment approach (Kenter *et al.*, 2011).
(4) Land-cover based approach (Burkhard *et al.*, 2015; Burkhard *et al.*, 2009): This method considers the land use patches alone, but ignores the mosaics of boundaries, which are also important in landscape assessment (Martín de Agar, Ortega and de Pablo, 2016). Also, it does not support detailed evaluation and applies only to large scale data.

There are only 26 articles with a title that includes the term 'landscape services' (in SCOPUS search, on November 14, 2018). 17 of them focus on assessment and (or) quantification mapping of LS, which is a critical topic. In order to merge with landscape research, the existing literature usually combines the four methods used for ES to asses LS. Compared to the ES assessment results, the results of LS assessments can provide more accurate and valuable information, therefore, providing a knowledge base for broader decision processes. There are several reasons illustrating the importance of LS assessment results.

First, LS assessment results are helpful for community/regional stakeholders and land managers. For example, Kienast *et al*. (2009) utilised expert-and literature-driven binary links in Europe, which generates a broad-scale multi-functionality assessment framework of LS for land managers. Additionally, the public participatory approach utilises the knowledge of community stakeholders (Fagerholm *et al*., 2012) to reach a collaborative, bottoms-up landscape management approach, and capture the non-utilitarian value of landscapes and sensitivity to cultural services. It is also used in land management by the American Indian tribes (Carver *et al*., 2009) and conservation efforts in the Amazon (Bernard, Barbosa and Carvalho, 2011). However, it is limited by the experience and knowledge of stakeholders. Wu *et al*. (2013) combined the results of a field survey with spatial index data that identify hotspots and the relationships between LS in Beijing and its surrounding areas, illustrating the importance of LS for stakeholders.

Second, LS can be used in broader decision-making processes, especially in landscape planning. Willemen *et al*. (2012) proposed a modelling approach, which tackles the multi-functional characteristics of a landscape, classifies different spatial levels, and proposes a spatially explicit method to show the potential relevance of LS for decision-making in Gelderse Vallei, Netherlands. Hermann *et al*. (2014) assessed and visualised an array of LS, considering different spatial scales and levels of services, to adopt three different approaches - the Broader Habitat Approach, the Socio-cultural Approach, and the Landform Approach. They provide an efficient tool to support cross-border landscape planning processes.

Furthermore, in order to promote landscape sustainability research, a LS approach is necessary. Fang *et al*. (2015) provided the LS capability-flow-demand framework that can utilise LS for practical applications. Nowak and Grunewald (2018) assessed the LS supply in seven different study areas in the Malopolska Province, and characterised landscape sustainability by combining a qualitative and a quantitative analysis.

In conclusion, the assessment and mapping approaches of LS are mainly derived from ES but have distinctive features. The former synthesizes various methods during the evaluation and visualization of LS in the landscape dimension to help meet human needs, enhances the participation of the public and stakeholders, promotes practical applications of the concept, and addresses landscape sustainability in the context of trans-disciplinary research.

However, some factors of LS (landscape patterns, heterogeneity, elements and features) are not fully understood. Additionally, there is insufficient research based on practical case studies. Furthermore, landscapes are always in a dynamic state, hence, ES and LS are also dynamic changes in the development process. The dynamics regarding LS are significantly relevant to environmental management and decision making. Therefore, identifying these dynamic changes and determining its possible critical thresholds will be among the challenges for future researchers.

Conclusions and Recommendations

Although the concept of LS is derived from ES, and they are treated as synonyms in many studies, LS generate higher added value and provide a common ground unifying various disciplines (Termorshuizen and Opdam, 2009). Furthermore, LS can meet the demands of different stakeholders, promote broad-scale decision-making processes, and enhance landscape sustainability research. Hence, in future studies, LS should be regarded as a separate concept, instead of being a substitute for ES, and pursued in detail.

First, it is essential to develop and clarify the definition and typology of LS associated with landscape characteristics related to spatial patterns and the dimension of human activities. However, according to the typology of ES in the literature, one universal classification system does not exist since different disciplines and scientific purposes have led to different classification standards. Although Vallés-Planells, Galiana and Van Eetvelde (2014) and Bastian *et al*. (2014) have attempted to classify LS, it is still challenging to identify a fundamental category.

Second, the assessment and quantification methods for ES and LS are almost the same. Although in most studies on LS, several assessment methods are applied at the same time. Therefore, the next step would be to develop specific methods or tools to support the assessment and quantification of LS, and to establish a comprehensive framework involving socio-cultural, ecological, and economic values to support decision-making processes.

The existing literature has depended on the data on land use to ignore other choices. There is a large amount of data waiting to be explored. For example, mapping LS are not related to land use alone, but also to landscape features. The current maps of landscape functions and services include models and geo-statistical simulations (Ungaro, Zasada and Piorr, 2014), on-ground observations and spatial indicators (Gulickx *et al*., 2013), and the knowledge of community stakeholders about aerial images (Fagerholm *et al.,* 2012). Although the map of landscape functions should also show heterogeneity in the quantity and quality of services provision (Meyer and Grabaum, 2008), spatially explicit data on landscape heterogeneity is still unavailable.

Additionally, spatial and temporal scales are key issues in the assessment and mapping of LS, since the landscape perceptions of stakeholders, regarding both supply and demand, are varied at different scales.

The last but not least, at present, the world is seriously threatened by climate change, and scholars have begun to explore solutions based on ES. When it comes to concepts such as carbon sinks, it is necessary to mention mountain ES. Many current studies have assessed the trade-offs (Briner *et al.*, 2013; Mina *et al.*, 2017), and influencing factors (Arjjumend, Shibata and Fakana, 2018; Boix-Fayos *et al*., 2020), and

temporal and spatial variations of mountain ES in the context of climate change. Even if the climate change factors are not considered in the assessment, the studies show that the trade-offs of MES in future scenarios are significantly affected by climate change (Briner *et al.*, 2013). Therefore, continued scientific research and case studies are needed in order to achieve a comprehensive methodology to assess and map LS, with respect to landscape features, patterns, processes, and scales, as well as pay more attention to how to combine mountain ES with LS theory and methods.

In conclusion, the LS research community is still in the early stages. Further effort is required to improve this scientific knowledge bases and overcome obstacles. Taking the development of ES as a reference, more studies and projects on LS should be conducted, similar to the TEEB and the CICES project for ES.

Acknowledgements

References

Aertsen, W., Kint, V., Muys, B. and Van Orshoven, J. (2012). Effects of scale and scaling in predictive modelling of forest site productivity. *Environmental Modelling and Software*, 31: 19–27. DOI: https://doi.org/10.1016/j.envsoft.2011.11.012

Ahern, J., Cilliers, S. and Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design : A framework for supporting innovation. *Landscape and Urban Planning*, 125: 254–259. DOI: https://doi.org/10.1016/j.landurbplan.2014.01.020

Antrop, M. (2000). Background concepts for integrated landscape analysis. *Agriculture, Ecosystems and Environment*, 77(1–2): 17–28. DOI: https://doi.org/10.1016/S0167-8809(99)00089-4

Arjjumend, H., Shibata, S. and Fakana, S. (2018). Ecosystem Services of Forest Ecosystem in Nechisar National Park, Ethiopia: Identifying the Challenges and Conservation Measures. *Journal of Global Resources*, 4(2): 18–29. Available online at: https://www.researchgate.net/publication/326097643_ECOSYSTEM_SERVICES_OF_FOREST_E COSYSTEM_IN_NECHISAR_NATIONAL_PARK_ETHIOPIA_IDENTIFYING_THE_CHALLE NGES_AND_CONSERVATION_MEASURES [accessed 22 October 2022]

Bastian, O., Grunewald, K., Syrbe, R.U., Walz, U. and Wende, W. (2014). Landscape services: the concept and its practical relevance. *Landscape Ecology*, 29(9): 1463–1479. DOI: https://doi.org/10.1007/s10980-014-0064-5

Bernard, E., Barbosa, L. and Carvalho, R. (2011). Participatory GIS in a sustainable use reserve in Brazilian Amazonia: Implications for management and conservation. *Applied Geography*, 31(2): 564–572.

Boix-Fayos, C., Boerboom, L.G.J., Janssen, R., Martínez-Mena, M., Almagro, M., Pérez-Cutillas, P., Eekhout, J.P.C., Castillo, V. and de Vente, J. (2020). Mountain ecosystem services affected by land use changes and hydrological control works in Mediterranean catchments. *Ecosystem Services*, 44(October 2019): 101136.

Boyd, J. and Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics*, 63(2–3): 616–626. DOI: https://doi.org/10.1016/j.ecolecon.2007.01.002

Briner, S., Huber, R., Bebi, P., Elkin, C., Schmatz, D.R. and Grêt-Regamey, A. (2013). Trade-offs between ecosystem services in a mountain region. *Ecology and Society*, 18(3): 35. DOI: https://doi.org/10.5751/ES-05576-180335

Burkhard, B., Kroll, F., Müller, F. and Windhorst, W. (2009). Landscapes' capacities to provide ecosystem services - A concept for land-cover based assessments. *Landscape Online*, 15(1): 1–22.

OPEN ACCESS Freely available online

Burkhard, B., Kroll, F., Nedkov, S. and Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. *Ecological Indicators*, 21: 17–29. DOI: https://doi.org/10.1016/j.ecolind.2011.06.019

Burkhard, B., Müller, A., Müller, F., Grescho, V., Anh, Q., Arida, G., Bustamante, J., Victor J., Van C. H., Heong, K. L., Escalada, M., Marquez, L., Thanh T., Dao T., Sylvia B. and Settele, J. (2015). Land cover-based ecosystem service assessment of irrigated rice cropping systems in southeast Asia-An explorative study. *Ecosystem Services*, 14: 76–87. DOI: https://doi.org/10.1016/j.ecoser.2015.05.005

Cairns, J. (1997). Protecting the delivery of ecosystem services. *Ecosystem Health*, 3(3): 185-194.

Carver, S., Watson, A., Waters, T., Matt, R., Gunderson, K. and Davis, B. (2009). Developing computer-based participatory approaches to mapping landscape values for landscape and resource management (pp. 431–448). Springer, Dordrecht.

Costanza, R. (2008). Ecosystem services: Multiple classification systems are needed. *Biological Conservation*, 141(2): 350–352. DOI: https://doi.org/10.1016/j.biocon.2007.12.020

Costanza, R., D´Arge, R., De Groot, R.S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, Sh., O´Neill, R., Pauelo, J., Raskin, R., Sutton, P., van den B. and Man den Belt, M. (1997). The value of the word´s ecosystem services and natural capital. *Nature*, 387: 253–260.

Costanza, R., De Groot, R. S., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S. and Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services*, 28: 1–16. DOI: https://doi.org/10.1016/j.ecoser.2017.09.008

Daily, G.C. (1997). *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington, DC: Island Press.

De Groot, R.S. (1992). *Functions of nature : evaluation of nature in environmental planning, management and decision making.* Groningen: Wolters-Noordhoff BV.

De Groot, R. S., Alkemade, R., Braat, L., Hein, L. and Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, 7(3): 260–272. DOI: https://doi.org/10.1016/j.ecocom.2009.10.006

De Groot, R.S. and Hein, L. (2007). Concept and valuation of landscape functions at different scales BT - Multifunctional Land Use: Meeting Future Demands for Landscape Goods and Services. In: Ü. Mander, H. Wiggering, and K. Helming (Eds.) (pp. 15–36). Berlin, Heidelberg: Springer. DOI: https://doi.org/10.1007/978-3-540-36763-5_2

De Groot, R.S., Wilson, M.A. and Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41(May): 1–20. DOI: https://doi.org/10.1016/S0921-8009(02)00089-7

Duarte, G.T., Santos, P.M., Cornelissen, T.G., Ribeiro, M.C. and Paglia, A.P. (2018). The effects of landscape patterns on ecosystem services: meta-analyses of landscape services. *Landscape Ecology*, 33(8): 1247–1257. DOI: https://doi.org/10.1007/s10980-018-0673-5

Ehrlich, P. and Ehrlich, A. (1981). Extinction: the causes and consequences of the disappearance of species. New York: Random House.

Fagerholm, N., Käyhkö, N., Ndumbaro, F. and Khamis, M. (2012). Community stakeholders' knowledge in landscape assessments - Mapping indicators for landscape services. *Ecological Indicators*, 18: 421–433. DOI: https://doi.org/10.1016/j.ecolind.2011.12.004

Fang, X., Wenwu, Z. and Bojie Fu, J.D. (2015). Landscape service capability , landscape service flow and landscape service demand : A new framework for landscape services and its use for landscape sustainability assessment. *Progress in Physical Geography*, 39(6): 817-836. DOI: https://doi.org/10.1177/0309133315613019

Fisher, B., Turner, R.K. and Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, 68(3): 643–653. DOI: https://doi.org/10.1016/j.ecolecon.2008.09.014

Gulickx, M.M.C., Verburg, P.H., Stoorvogel, J.J., Kok, K. and Veldkamp, A. (2013). Mapping landscape services: A case study in a multifunctional rural landscape in the Netherlands. *Ecological Indicators*, 24: 273–283. DOI: https://doi.org/10.1016/j.ecolind.2012.07.005

Haines-Young, R. and Potschin, M. (2009). *Methodologies for defining and assessing ecosystem services. Final Report, JNCC*. DOI: https://doi.org/Project Code C08-0170-0062, 69 pp.

Haines-Young, R. and Potschin, M. (2010a). Proposal for a common international classification of ecosystem goods and services (CICES) for integrated environmental and economic accounting. Report to the European Environment Agency. Department of Economic and Social Affairs Statistics Division, United Nations, Nottingham, UK.

Haines-Young, R. and Potschin, M. (2010b). The links between biodiversity, ecosystem services and human well-being. *Ecosystem Ecology*, 1: 110-139. DOI: https://doi.org/10.1017/CBO9780511750458.007

Hein, L., van Koppen, K., De Groot, R.S. and van Ierland, E.C. (2006). Spatial scales, stakeholders and the valuation of ecosystem services. *Ecological Economics*, 57(2): 209–228. DOI: https://doi.org/10.1016/j.ecolecon.2005.04.005

Hermann, A., Kuttner, M., Hainz-Renetzeder, C., Konkoly-Gyuró, É., Tirászi, Á., Brandenburg, C., Allex B., Ziener K. and Wrbka, T. (2014). Assessment framework for landscape services in European cultural landscapes: An Austrian Hungarian case study. *Ecological Indicators*, 37(PART A): 229–240. DOI: https://doi.org/10.1016/j.ecolind.2013.01.019

Kenter, J.O., Hyde, T., Christie, M. and Fazey, I. (2011). The importance of deliberation in valuing ecosystem services in developing countries-Evidence from the Solomon Islands. *Global Environmental Change*, 21(2): 505–521. DOI: https://doi.org/10.1016/j.gloenvcha.2011.01.001

Kienast, F., Bolliger, J., Potschin, M., De Groot, R. S., Verburg, P. H., Heller, I., Wascher, D. and Haines-Young, R. (2009). Assessing landscape functions with broad-scale environmental data: Insights gained from a prototype development for Europe. *Environmental Management*, 44(6): 1099–1120. DOI: https://doi.org/10.1007/s00267-009-9384-7

Lautenbach, S., Kugel, C., Lausch, A. and Seppelt, R. (2011). Analysis of historic changes in regional ecosystem service provisioning using land use data. *Ecological Indicators*, 11(2): 676–687. DOI: https://doi.org/10.1016/j.ecolind.2010.09.007

Leones, J. (1994). Landscape Services: An Urban Agricultural Sector. *Agribusiness*, 10(1): 13–26.

Liquete, C., Kleeschulte, S., Dige, G., Maes, J., Grizzetti, B., Olah, B. and Zulian, G. (2015). Mapping green infrastructure based on ecosystem services and ecological networks : A Pan-European case study. *Environmental Science and Policy*, 54: 268–280. https://doi.org/10.1016/j.envsci.2015.07.009

MA (Millennium Ecosystem Assessment) (2005). *Ecosystems and Human Well-being: Synthesis*. Washington, DC.: Island Press.

Mander, Ü., Helming, K. and Wiggering, H. (2007). Multifunctional land use: meeting future demands for landscape goods and services. In: *Multifunctional land use* (pp. 1–13). Berlin, Heidelberg: Springer.

Martín de Agar, P., Ortega, M. and de Pablo, C.L. (2016). A procedure of landscape services assessment based on mosaics of patches and boundaries. *Journal of Environmental Management*, 180: 214–227. DOI: https://doi.org/10.1016/j.jenvman.2016.05.020

McCauley, D.J. (2006). Selling out on nature. *Nature*, 443: 27. DOI: https://doi.org/10.1038/443027a

Meyer, B.C. and Grabaum, R. (2008). MULBO: Model framework for Multicriteria Landscape Assessment and Optimisation. A support system for spatial land use decisions. *Landscape Research*, 33(2): 155–179. DOI: https://doi.org/10.1080/01426390801907428

Mina, M., Bugmann, H., Cordonnier, T., Irauschek, F., Klopcic, M., Pardos, M. and Cailleret, M. (2017). Future ecosystem services from European mountain forests under climate change. *Journal of Applied Ecology*, 54(2): 389–401. DOI: https://doi.org/10.1111/1365-2664.12772

Müller, F., Jones, K.B., Krauze, K., Li, B.L., Victorov, S., Petrosillo, I. and Zurlini, G. (2008). Landscape approaches to assess environmental security: summary, conclusions, and recommendations. In: *Use of landscape sciences for the assessment of environmental security* (pp. 475–486). Springer. Dordrecht.

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, Kai M.A., Daily, G.C., Goldstein, J., Kareiva, P. M., Lonsdorf, E., Naidoo, R., Ricketts, T. H. and Shaw, M.R. (2009). Modeling multiple ecosystem services, biodiversity conservation, commodity production, and

tradeoffs at landscape scales. *Frontiers in Ecology and the Environment*, 7(1): 4–11. DOI: https://doi.org/10.1890/080023

Niemelä J., Saarela S-R., Söderman T., Kopperoinen L., Yli-Pelkonen V., Väre S., K.D.J. (2010). Using the ecosystem services approach for better planning and conservation of urban green spaces : a Finland case study. *Biodiversity and Conservation*, 19 (11): 3225–3243. DOI: https://doi.org/10.1007/s10531-010-9888-8

Nowak, A. and Grunewald, K. (2018). Landscape sustainability in terms of landscape services in rural areas: Exemplified with a case study area in Poland. *Ecological Indicators*, 94(February): 12–22. DOI: https://doi.org/10.1016/j.ecolind.2018.01.059

Odum, E.P. and Odum, H.T. (1972). Natural areas as necessary components of man's total environment. *Trans North Am Wildl Nat Res Conf*, 3: 178–189.

Serna-Chavez, H.M., Schulp, C.J.E., Van Bodegom, P.M., Bouten, W., Verburg, P.H. and Davidson, M.D. (2014). A quantitative framework for assessing spatial flows of ecosystem services. *Ecological Indicators*, 39(April): 24–33. DOI: https://doi.org/10.1016/j.ecolind.2013.11.024

Sherrouse, B.C., Clement, J.M. and Semmens, D.J. (2011). A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. *Applied Geography*, 31(2): 748–760. DOI: https://doi.org/10.1016/j.apgeog.2010.08.002

Sun, J., Liu, L., Müller, K., Zander, P., Ren, G., Yin, G. and Hu, Y. (2018). Surplus or deficit? Spatiotemporal variations of the supply, demand, and budget of landscape services and landscape multifunctionality in suburban Shanghai, China. *Sustainability (Switzerland)*, 10(10): 1–21. DOI: https://doi.org/10.3390/su10103752

Syrbe, R.U. and Walz, U. (2012). Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics. *Ecological Indicators*, 21: 80–88. DOI: https://doi.org/10.1016/j.ecolind.2012.02.013

TEEB (2010). *The economics of ecosystems and biodiversity: ecological and economic foundations*. (P. Kumar, Ed.). London: Routledge.

Termorshuizen, J.W. and Opdam, P. (2009). Landscape services as a bridge between landscape ecology and sustainable development. *Landscape Ecology*, 24(8): 1037–1052. DOI: https://doi.org/10.1007/s10980-008-9314-8

Ungaro, F., Zasada, I. and Piorr, A. (2014). Mapping landscape services, spatial synergies and trade-offs. A case study using variogram models and geostatistical simulations in an agrarian landscape in North-East Germany. *Ecological Indicators*, 46: 367–378. DOI: https://doi.org/10.1016/j.ecolind.2014.06.039

Vallés-Planells, M., Galiana, F. and Van Eetvelde, V. (2014). A Classification of Landscape Services to Support Local Landscape. *Ecology & Society*, 19(1): 1–11. https://doi.org/10.5751/ES-06251-190144

Wang, Y. and Dai, E. (2020). Spatial-temporal changes in ecosystem services and the trade-off relationship in mountain regions: A case study of Hengduan Mountain region in Southwest China. *Journal of Cleaner Production*, 264: 121573. DOI: https://doi.org/10.1016/j.jclepro.2020.121573

Westerink, J., Opdam, P., van Rooij, S. and Steingröver, E. (2017). Landscape services as boundary concept in landscape governance: Building social capital in collaboration and adapting the landscape. *Land Use Policy*, 60: 408–418. DOI: https://doi.org/10.1016/j.landusepol.2016.11.006

Willemen, L., Veldkamp, A., Verburg, P. H., Hein, L. and Leemans, R. (2012). A multi-scale modelling approach for analysing landscape service dynamics. *Journal of Environmental Management*, 100: 86–95. DOI: https://doi.org/10.1016/j.jenvman.2012.01.022

Willemen, L. (2010). Mapping and modelling multifunctional landscapes. Wageningen University and Research, the Netherlands.

Wu, J. (2013). Landscape sustainability science: Ecosystem services and human well-being in changing landscapes. *Landscape Ecology*, 28(6): 999–1023. DOI: https://doi.org/10.1007/s10980-013-9894-9

OPEN ACCESS Freely available online

Wu, J., Feng, Z., Gao, Y. and Peng, J. (2013). Hotspot and relationship identification in multiple landscape services: A case study on an area with intensive human activities. *Ecological Indicators*, 29: 529–537. DOI: https://doi.org/10.1016/j.ecolind.2013.01.037

Young, R.F. (2010). Managing municipal green space for ecosystem services. *Urban Forestry & Urban Greening*, 9(4): 313–321. DOI: https://doi.org/10.1016/j.ufug.2010.06.007

Zhang, S. & Muñoz Ramírez, F. (2019). Assessing and mapping ecosystem services to support urban green infrastructure: The case of Barcelona, Spain. *Cities*, 92: 59–70. DOI: https://doi.org/10.1016/j.cities.2019.03.016.

OPEN ACCESS Freely available online

Author's Declarations and Essential Ethical Compliances

Research involving human bodies (Helsinki Declaration)
Has this research used human subjects for experimentation?   No

Research involving animals (ARRIVE Checklist)
Has this research involved animal subjects for experimentation?   No

Research involving Plants
During the research, did the author follow the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora?   Yes

Research on Indigenous Peoples and/or Traditional Knowledge
Has this research involved Indigenous Peoples as participants or respondents?   No

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
Has author complied with PRISMA standards?   Yes

Competing Interests/Conflict of Interest
Author has no competing financial, professional, or personal interests from other parties or in publishing this manuscript.

Rights and Permissions